Title page

The running head: Modified technique for common carotid artery transposition in standing horses

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Abstract

Objectives: To describe a modified technique for permanent translocation of the common carotid artery to a subcutaneous position in standing horses.

Study design: Experimental study

Animals: Eight clinically healthy, adult Standardbred and Warmblood horses.

Methods: The surgery was performed with the horses standing under sedation and with local anesthesia. A combination of previously described techniques was used modifying the approach and closure of the incision. The right common carotid artery was approached through a linear skin incision dorsal and parallel to the jugular vein and through the brachiocephalicus and omohyoideus muscles. The artery was dissected free of its sheath and elevated to the skin incision with Penrose drains. The brachiocephalicus muscle was sutured in 2 layers underneath the artery leaving it in a subcutaneous position. The horses were allowed to heal for 3 weeks prior to catheterization of the artery.

Results: The transpositioned common carotid artery was successfully used for repeated catheterization in 6 out of 8 horses for a period of 10 weeks. None of the horses had intraoperative complications. Two horses developed mild peri-incisional edema that resolved spontaneously. Right-sided laryngeal hemiplegia was observed endoscopically in 2 horses postoperatively. Two horses developed complications (surgical site infection

and excessive periarterial fibrosis, respectively) that compromised the patency of the common carotid artery and precluded the catheterization.

Conclusions: The permanent translocation of the common carotid artery in a standing horse was successful in 6 out of 8 horses. An upper airway endoscopy postoperatively may be warranted as laryngeal hemiplegia may ensue.

Introduction

Repeated sampling of arterial blood and direct arterial blood pressure monitoring are required in many physiologic and pharmacologic experiments in animal models. The common carotid artery is frequently translocated to a subcutaneous position to facilitate repeated sampling or catheterization of the artery in large animals, such as sheep, cattle, and horses.[1-6] Different techniques have been described for subcutaneous translocation of the common carotid artery in anesthetized small ruminants.[1,3,6] In horses, the available literature on the procedure is scarce and is described for anesthetized horses.[2,5,7] A technique to translocate the common carotid artery in the horse was first described by Tavernor et al.[2] The common carotid artery was approached through a linear skin incision between the jugular vein and the brachiocephalicus muscle. The omohyoideus muscle was split to access the carotid sheath. The common carotid artery was elevated to the skin incision and supported subcutaneously by reapposing the omohyoideus muscle and with polyethylene tubing. The technique has subsequently been modified, including the creation of a skin flap over the jugular groove[5,7] and approach through the brachiocephalicus muscle instead of accessing the carotid sheath ventral to it.[7] The previously described technique involving the creation of a skin flap reported formation of seroma as complication in cases where suction drainage system was not utilized postoperatively.[5] In sheep and goats the reported complications of the permanent translocation of the common carotid artery include subcutaneous hematoma and abscess formation, occlusion of the elevated artery segment and necrosis of the skin flap.[6]

A surgical approach, similar to ours, has been previously described for temporary catheterization of the common carotid artery in a standing horse for occlusion of the internal carotid artery for the treatment of guttural pouch mycosis.[8] After coil embolization, the common carotid artery was released back to its deep location and muscle layers were reapposed. The technique was successful in standing horses and no perioperative complications occurred. However, this technique is only applicable for single catheterization of the artery.

The purpose of this article is to describe a modified technique for the permanent translocation of the common carotid artery to a subcutaneous position in the standing horse. The surgical approach combined the previously described linear skin incision[2] and approach through the brachiocephalicus muscle[7]. Use of a polyethylene tubing or postoperative suction system were omitted. In addition, method to reappose of the muscles layers underneath the translocated common carotid artery was modified.

Performing the surgery standing would avoid the costs and potential risks related to the general anesthesia of a horse. To the best of our knowledge, the permanent translocation of the common carotid artery has not previously been described in a standing horse.

Materials and methods

The study was approved by the National Animal Experiment Board of Finland and conducted according to the Finnish Act on Animal Experimentation. This is consistent with the U.S. National Institutes of Health "Guide for the Care and Use of Laboratory Animals".

Eight healthy Standardbred and Warmblood horses (3 geldings and 5 mares) of ages 6–15 years were used in the study. The horses showed no signs of systemic illness based on clinical examination and hematological analysis of blood samples.

The surgery was carried out with the horses standing and restrained in stocks. The head was supported to remain at the level of the withers by cross-tying the horse. All the procedures were performed on the right common carotid artery. A 12G polytetrafluoroethylene intravenous catheter was placed aseptically into the left jugular vein. All the horses were preoperatively medicated with penicillin G procaine 20,000 IU/kg intramuscularly [IM] and flunixin meglumine 1.1 mg/kg intravenously [IV]. Sedation was accomplished by intravenous injection of detomidine hydrochloride (5 μg/kg) and butorphanol tartrate (5 μg/kg), and maintained either by continuous rate infusion of detomidine hydrochloride (30 μg/kg/hr) or repeated boluses of detomidine hydrochloride (2–3 μg/kg) IV to effect. Boluses of detomidine hydrochloride were given if horses started to move the head during the surgery.

On the right side of the neck, the hair was clipped on the proximal and middle thirds, continuing from the ventral midline of the neck approximately 20 centimeters dorsally. The clipped area was aseptically prepared for surgery; the skin was scrubbed with chlorhexidine gluconate skin cleanser and then wiped with alcohol solution. The surgical area was draped sterilely.

Local anesthesia (12–15 mL of lidocaine 2 mg/mL) was infiltrated at the surgical site subcutaneously on the dorsal aspect of the jugular groove prior to the start of the operation. Additional local anesthesia (5 mL of lidocaine 2 mg/mL) was infiltrated in the brachiocephalicus and omohyoideus muscles if needed during the operation.

The skin was placed under tension dorsally using a sterile hand dorsal to the jugular groove. A 10–12 cm linear skin incision was made with a number 22 blade at the junction of the proximal and middle third of the neck, starting approximately 15 cm distal to the ramus of the mandible. The incision was made approximately 2 cm dorsally and parallel to the jugular groove, also incising the cutaneous coli muscle (Fig 1). The edges of the incision were undermined approximately 10 mm superficial to fascia of the brachiocephalicus muscle using Metzenbaum scissors to create space for later closure of the muscle layers. The fascia of the brachiocephalicus muscle was sharply incised and the brachiocephalicus muscle was bluntly split using Metzenbaum scissors. The underlying omohyoideus muscle was identified and bluntly split, digitally or using Metzenbaum scissors, until the carotid sheath was visible. Weitlaner retractors were used to facilitate the visibility and dissection.

The carotid sheath was bluntly opened with Halsted mosquito forceps and the common carotid artery and vagosympathetic trunk were identified (Fig 2). The opening of the carotid sheath was digitally extended proximally and distally until it was the same length as the incision. The carotid artery was then, digitally and using Halsted mosquito forceps, separated from the carotid sheath and the vagosympathetic trunk. If present, small branches of the carotid artery were identified, double ligated using poliglecaprone 25 USP 2-0, and severed. Approximately 7 cm of the artery was dissected free from the sheath, so that it could be relocated subcutaneously without excessive tension or restriction by the carotid sheath. Two Penrose drains, one proximally and one distally, were then placed around the carotid artery and secured with Halsted mosquito forceps. The artery was elevated to the skin incision by pulling the drains. The incision was carefully checked for possible bleeding vessels and the surgical area was flushed with sterile saline.

The fascia of the omohyoideus muscle and the overlying, deep part of the brachiocephalicus muscle were sutured with a simple interrupted pattern using polydioxanone USP 0 or polyglactin 910 USP 0. The superficial part of the brachiocephalicus muscle and the superficial fascia of the brachiocephalicus muscle were then closed with an interrupted horizontal mattress pattern using polydioxanone USP 0 or polyglactin 910 USP 0, leaving the common carotid artery superficial to it (Fig. 3). The mattress pattern sutures were placed a minimum of 5 mm away from the incision of the fascia of the brachiocephalicus muscle. The Penrose drains were then released and the surgical area was inspected for any bleeding. The surgical site was flushed with saline prior to closure of the skin.

The subcutis layer was separately closed in 1 horse using a simple continuous pattern with polyglactin 910 USP 2-0. In all the other horses, the subcutis layer was not closed. The skin was closed with either a simple interrupted or Ford interlocking pattern using polyamide 6, USP 2-0. A stent bandage of sterile gauze was sutured over the incision in 5 horses using polyamide 6, USP 2-0. The suture pattern consisted of 3 interrupted sutures using a single bite in the skin on each side of the bandage. The stent bandage was left in place for 24–48 hours.

Postoperatively, penicillin G procaine 20,000 IU/kg IM twice daily and flunixin meglumine 1.1 mg/kg orally once daily were continued for 3–5 days. Monitoring of the horses included recording the general attitude, appetite, amount of defecation and performing a clinical examination 3 times a day. The surgical area was monitored daily for swelling, a visible pulse in the translocated common carotid artery segment, and incisional discharge until removal of the skin sutures. The horses were fed from a hay net during the first postoperative week. The skin sutures were removed 12–14 days postoperatively. After the removal of the skin sutures, the pulse of the elevated artery segment was also palpated. If any incisional discharge was noticed or edema remained after removal of the skin sutures, an ultrasound examination was performed.

Observed complications were recorded. Incisional dehiscence, infection, hematoma or seroma at the surgical site were considered as minor complications. Inability to use the translocated common carotid artery segment for catheterization was considered as major complication.

The elevated arteries were considered to be ready for use after the operation when all the edema had resolved, a pulse of the elevated artery segment was clearly palpable subcutaneously at the surgical site, and the skin incision had completely healed.

Six out of the 8 horses had an upper airway endoscopy at rest performed at 3 months postoperatively in order to obtain a bronchoalveolar sample related to another study.

Results

All the horses were operated without complications during the surgery. The results are summarized in Table 1. In 2 horses (#6 and #8), a branch of the common carotid artery needed to be ligated and severed. In 2 horses (#7 and #8), hemorrhage occurred from the brachiocephalicus muscle, which was controlled with ligation of the vessels.

Six out of the 8 horses were used for experimental purposes after translocation of the common carotid artery. The right common carotid artery was repeatedly catheterized (BD Arterial Cannula 20G/1.10 mm x 45 mm) throughout a period of 10 weeks. The elevated artery was ready to be used in 3 weeks in these 6 horses. Catheterization was performed weekly according to the study design and a catheter was used for repeated blood sampling, direct blood pressure monitoring, and measurement of cardiac output by the lithium dilution method. A catheter was in place for a maximum of 3 hours and was secured in place with sutures. No complications occurred during the use of the artery.

In 2 out of 8 horses (#1 and #7), mild, non-painful edema developed around the incision. The edema spontaneously resolved within 6 days. Right-sided laryngeal hemiplegia was observed in 2 out of the 6 horses (#1 and #5) in which an upper airway endoscopy was performed 3 months after the surgery. The hemiplegia was subjectively graded as 3C in horse #1 and as 3B in horse #5.[9] The horses showed no clinical signs of airway disease at rest.

In 2 horses (#3 and #4), complications occurred that compromised patency of the common carotid artery and precluded the use the affected artery in the subsequent experiments. A surgical site infection occurred in 1 horse and excessive periarterial fibrosis at the surgical site in another.

Horse #3 developed mild edema around the incision during 24 hours after the operation. The edema increased to a moderate amount at 3 days postoperatively and the incision started to discharge serosanguineous fluid. The discharge became purulent 7 days after the operation and an incisional infection was confirmed with bacterial culture of *Clostridium* sp. and *Enterococcus faecalis*. On ultrasound examination, the common carotid artery was patent proximal and distal to the incision, but not in the surgical area. The use of color Doppler ultrasonography confirmed the absence of blood flow. There was also abnormally thick heterogeneous tissue around the elevated carotid segment. The distal skin sutures were removed and the incision was flushed daily with saline. The horse received penicillin G procaine (20,000 IU/kg IM twice daily) and flunixin meglumine (1.1 mg/kg orally once daily) for 1 week. The rest of the sutures were removed 12 days postoperatively and local wound cleaning with saline continued. The horse remained afebrile and without systemic signs of illness throughout the treatment period, and the discharge from the incision resolved over 1 month. The follow-up ultrasonographic examination 1 month post-operatively revealed that the common carotid artery was no longer patent. The horse was excluded from the subsequent studies.

Horse #4 developed moderate, non-painful, subcutaneous edema around the incision postoperatively that resolved spontaneously in 6 days. The incision was clean and there

was no discharge. Thirteen days postoperatively, moderate, non-painful, dense swelling developed around the incision. The sutures were removed, and ultrasonographic examination revealed a moderate amount of heterogeneous tissue surrounding the common carotid artery beneath the incision. A marked reduction in the patency of the artery at the site of the incision was observed with color Doppler ultrasonography. The horse was excluded from the subsequent studies.

Discussion

Transposition of the common carotid artery was carried out in all 8 standing horses without intraoperative complications. Six of the 8 horses were successfully used in the subsequent studies, in which the elevated artery segment was repeatedly catheterized.

An adequate level of sedation and analgesia was achieved in all the horses and the procedure was well tolerated. Performing the transposition of the common carotid artery with the horse standing avoids risks related to general anesthesia and the recovery of the horse, while also reducing the time and costs of the procedure. The common carotid artery was readily accessed through the muscle layers in a standing horse.

The technique described in this study is a modification of previously described techniques to translocate the common carotid artery.[1-3,5-6,10] In the present study, the common carotid artery was approached through a linear skin incision, as described earlier.[2] Orsini and Roby presented an approach involving the creation of a skin flap over the jugular groove. The skin flap was performed in order to facilitate tissue identification and percutaneous puncture of the carotid artery. However, seroma formation was described in 8/14 horses in which a closed suction system was not applied postoperatively.[5] We observed no seroma formation postoperatively, although suction systems were not used. This could be related to the reduced dead space formation with the technique we used compared to the creation of a flap. In addition, closure of the muscles in 2 layers underneath the elevated carotid artery further reduces the dead space and may assist in the prevention of a seroma.

The carotid sheath has either been approached through the brachiocephalicus muscle,[8,9] ventral to it,[2,5] or through the sternocephalic muscle ventral to the jugular groove.[10] We chose to approach the common carotid artery directly through the brachiocephalicus and omohyoideus muscles. Approach through the brachiocephalicus muscle involved splitting of the muscle by blunt dissection, but provided a strong muscle fascia to be sutured underneath the common carotid artery. Furthermore, the jugular vein was not at risk of inadvertent puncturing during suturing, as it was located well away from the incision. Care was taken when dissecting muscle to avoid excessive trauma to the muscle and to close the dead space as much as possible in order to avoid seroma formation.

In the method described by Tavernor, the carotid artery segment was supported subcutaneously with a polyethylene tube.[2] In later modifications of the technique in horses, including ours, it has been observed that no support is needed to keep the artery elevated.[5,7] The use of foreign material to support the arterial segment could increase the risk of an excessive foreign body reaction, postoperative infection, and excessive fibrosis through mechanical irritation of the arterial wall.

Periarterial fibrosis developed in 1 horse at the surgical site and resulted in reduced patency of the elevated arterial segment. Occlusion of the artery by space-occupying lesions, like periarterial hematoma or abscess, has been reported as complication in sheep after permanent translocation of the common carotid artery.[6] Fibrosis surrounding the elevated artery in this horse may have led to stenosis by physical constriction and by reducing the elasticity of the surrounding tissues, thus reducing the pulsatility of the

artery. In addition, periarterial fibrosis complicates the catheterization of the artery even if the patency remained normal. This complication occurred in the only horse in which the subcutaneous tissues were closed with a separate layer, which could potentially contribute to fibrosis formation because of the presence of additional foreign material at the surgical site. Moreover, the artery should be dissected completely free of the surrounding carotid sheath prior to elevation to the incision. Failure to do so could potentially leave the carotid sheath constricting the elevated artery or result in excessive stretching of the artery when its being elevated to the incision. These factors may contribute to formation of fibrosis and consequently stenosis of the artery. In addition, while suturing the muscles, it is important to ensure that enough space is left for the artery segment to pass through muscles layers without constriction. The brachiocephalicus muscle and its superficial fascia were closed with a horizontal mattress pattern. A simple interrupted or continuous pattern may suffice to relieve the tension of the incision. However, using a mattress pattern, no suture material is in direct contact with the elevated artery, reducing the risk of inducing inflammation of the arterial wall by mechanical irritation of the suture material.

Damage to the vagosympathetic trunk that runs within the carotid sheath, and the right recurrent laryngeal nerve parallel to the trachea, should be avoided when elevating the carotid artery free of its sheath. Two out of 6 horses showed signs of right-sided laryngeal hemiplegia on endoscopic examination of the larynx postoperatively. Postoperative airway endoscopy was not performed for the 2 horses that were excluded from the subsequent studies. Laryngeal hemiplegia may be a consequence of damage to the recurrent laryngeal nerve or to the vagus nerve within the vagosympathetic trunk.[11]

We did not observe other clinical signs related to the damage of the vagosympathetic trunk, such as Horner's syndrome or dysfunction of the pharynx.[11] Therefore, we believe that damage to the recurrent laryngeal nerve was more likely than damage to the vagus nerve in those cases. Endoscopy of the upper respiratory tract of the horses prior to surgery was not performed. However, given the rarity of the condition on the right side,[12] it is likely that surgical manipulation together with inflammation contributed to this. Laryngeal hemiplegia has been reported as a potential complication after surgery in the neck region.[12] Loss of nerve function could occur through failure of impulse conduction (type I injury) or through direct damage to the axonal structures (type II injury).[13,14] Type I injury, neurapraxia, results, for example, from excessive compression of the nerves, which could be caused by postsurgical edema or damage to the myelin sheath, that may be caused by the manipulation during the surgery. This type of nerve damage is usually reversible, although it may persist months, in comparison to type II injury, in which prognosis for recovery is poor and therefore nerve function may be permanently lost.[14] Either type of injury of the right recurrent laryngeal nerve in this case is possible. A damage due to surgical manipulation or inflammation seems plausible as an excessive compression due to postoperative edema would also be likely to affect the vagosympathetic trunk, as it is very closely located. Careful tissue manipulation is needed to avoid surgical trauma to the nerves and to reduce postoperative inflammation. In addition, the use of non-steroidal anti-inflammatory medication peri- and postoperatively could aid in reducing later surgical site inflammation. However, as the number of horses in our study was low and the postoperative status of the larynx in 2 horses remained unknown, the true risk of laryngeal hemiplegia following this procedure should be further investigated with a larger number of horses.

In the present study, surgical site infection occurred in 1 horse, which led to occlusion of the elevated artery segment and precluded the use of the horse in cardiovascular studies. The reason for the surgical site infection was unknown. Strict asepsis was followed during the surgery and there were no intraoperative complications, such as excessive hemorrhage. However, performing the surgery standing in an examination room in comparison to operating on an anesthetized horse in a surgery room could potentially expose the surgical site to contamination. A stent bandage was not used postoperatively in this horse, which may have exposed the incision to contamination or contributed to the formation of edema that preceded the infection. Covering the incision for example with a stent bandage or a sterile wrap protects the incision while the initial seal of the skin occurs. In addition, it may help to prevent the formation of a hematoma and/or seroma.

An ultrasound-guided technique to catheterize the common carotid artery in its deep location has also been described.[15,16] This technique avoids the surgical transposition of the common carotid artery, but the catheterization needs to be assisted with ultrasonography. We believe that a subcutaneously located common carotid artery is more readily catheterized repeatedly, although this requires surgery prior to the start of the experiment. Furthermore, if several catheters are simultaneously used in jugular veins in addition to the arterial catheter, the subcutaneous location of the carotid artery in the proximal part of the neck may facilitate catheterization without compromising the jugular veins.

After a permanent transposition of the common carotid artery the horses may have a higher risk for fatal hemorrhage if they sustain a laceration to the right side of the neck at the site of the surgery. However, we have observed no complications related to the subcutaneous location of the artery and the horses were managed and turned out normally. The pulse of the translocated common carotid artery has remained visible and palpable subcutaneously 24 months postoperatively in the two horses that are is still in the hospital herd. In order to decrease the risk for fatal hemorrhage in the event of a neck laceration, a reversal of the common carotid artery back to its deep location could be considered. However, the benefits and risks of such operation remain to be investigated.

In our study, the translocated artery segment was successfully catheterized for a period of 10 weeks in 6 horses. During this time period, we encountered no difficulties in catheterization of the artery and observed no changes in cardiovascular parameters of the horses. This is comparable with a previous report in which a common carotid artery segment was translocated subcutaneously under general anesthesia in horses and successfully used for 12 weeks.[7] However, the long-term results of the procedure in horses should be determined with a study including a longer follow-up period.

The permanent translocation of the common carotid artery can be performed in a standing horse and it was well tolerated by the horses. It is an alternative to performing the procedure under general anesthesia, as the potential risks of anesthesia and recovery of the horse can be avoided while also reducing the costs of the surgery. An upper airway endoscopy postoperatively may be warranted prior to use of the horses in experimental studies as laryngeal hemiplegia may develop following the surgery.

Disclosure statement

The authors declare no conflict of interest related to this report.

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Figure legends

Figure 1: A photograph of the surgical area with drawn lines indicating the location of the incision in relation to the jugular vein and the common carotid artery on the right side of the neck. The blue line represents the jugular vein, the red line the common carotid artery, and the yellow line the skin incision.

Figure 2: A schematic illustration of the incision and the approach to the carotid sheath. The horse's head is to the right.

Figure 3: Surgical area on the right side of the neck, with the horse's head to the right. The common carotid artery is elevated to the incision with Penrose drains and the muscle layers are partially closed. The surgeon is holding the suture of the superficial part and fascia of the brachiocephalicus muscle before tying the knot.

471 Table

472 Table 1: Summary of the results in the individual horses.

473 * Common carotid artery

474 ** The outcome was considered successful if the subcutaneously translocated common

475 carotid artery was catheterized repeatedly without difficulties in the experiments

476 following the surgical procedure

477

Horse	**Ligation of the branches of the CCA***	**Use of a stent bandage**	**Closure of the subcutaneous layer**	**Complications**	**Outcome**
Horse 1	No	No	No	Right-sided laryngeal hemiplegia	Successful**
Horse 2	No	No	No	None	Successful**
Horse 3	No	No	No	Surgical site infection	Loss of patency of the translocated CCA*
Horse 4	No	Yes	Yes	Excessive periarterial fibrosis	Loss of patency of the translocated CCA*
Horse 5	No	Yes	No	Right-sided laryngeal hemiplegia	Successful**
Horse 6	Yes	Yes	No	None	Successful**
Horse 7	No	Yes	No	None	Successful**
Horse 8	Yes	Yes	No	None	Successful**